Data Science in Action #9

Studying Complex Systems – Simulating the Monopoly Board Game

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Data Scientist, SAS Austria

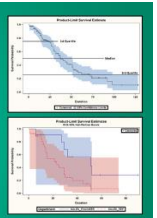
A Recording of this session can be found in my Data Science Webinar Playlist

Data Science Applications and Case Studies

Data Science
in Action: #1

Performing Headcount Survival Analysis for Employee Retention

Can assumptions about the average length of time intervals be made, even if most of the endpoints have not yet been observed?

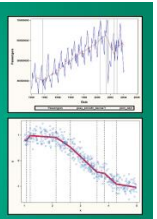


Survival analysis methods: Kaplan-Meier estimates
Cox Proportional Hazards regression
Survival Data Mining

Data Science
in Action: #2

Detecting Structural Changes and Outliers in Longitudinal Data

Can events and changes in the course over time be automatically detected?

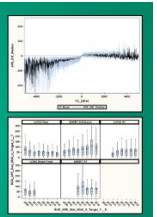


Smoothing Of Longitudinal Data
Multivariate Adaptive Regression Splines
Automatic Breakpoint Detection
Automatic Detection of Outliers with ARIMA Models

Data Science
in Action: #3

Explaining Forecast Errors and Deviations

Do the demand planners really improve forecast accuracy with their manual overwrites?

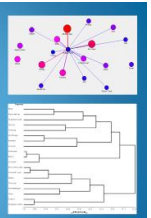


Linear Regression
Quantile Regression
Descriptive Statistics

Data Science
in Action: #4

Listening to Your Data – Discover Relationships with Unsupervised Analysis Methods

Can your data tell you stories about your analysis subjects, even if you don't ask explicitly?

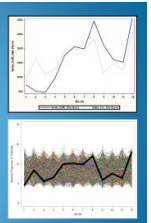


Unsupervised machine learning methods:
association analysis
variable clustering

Data Science
in Action: #5

Checking the Alignment with Predefined Pattern

Which customers show a behavior that is far from what you expected?

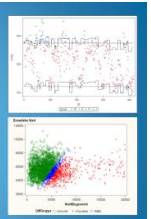


Chi2 independency test
Benford's law
Time Series Similarity

Data Science
in Action: #6

Proving a reference value that considers all available co-information

Can analytics help me to reduce the "Yes, but ... " sentences in my business discussions?

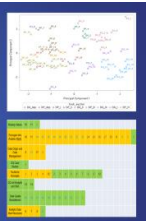


Linear Regression
Decision Trees
Time Series Analysis

Data Science
in Action: #7

Topic Search Documents and Clustering

Can I automatically find clusters of documents with similar content?

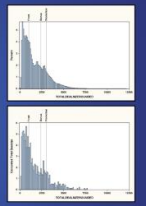


Text Mining
Text Parsing (Synonyme, Stemming, Stop-Listen)
Term by Document Weights

Data Science
in Action: #8

Using Monte Carlo Simulations to Understand the Outcome Distribution

When the sales manager looks at the project pipeline, does the sum of weighted averages give him or her a full picture?

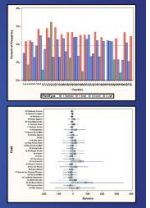


Monte Carlo Simulations
Mathematical Programming

Data Science
in Action: #9

Studying Complex Systems – Simulating the Monopoly Board Game

How can you simulate complex environments to get insight in the most frequent processes?



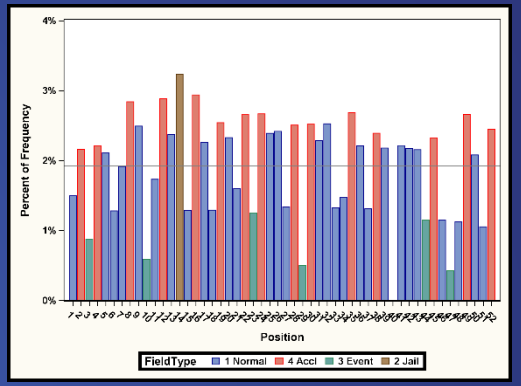
Monte Carlo Simulations

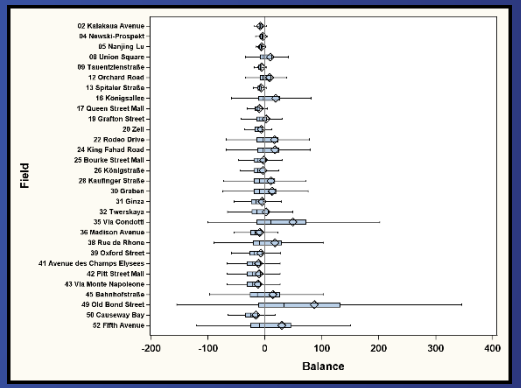
Data Science in Action: #9

Studying Complex Systems – Simulating the Monopoly Board Game

How can you simulate complex environments to get insight in the most frequent processes?

Monte Carlo Simulations





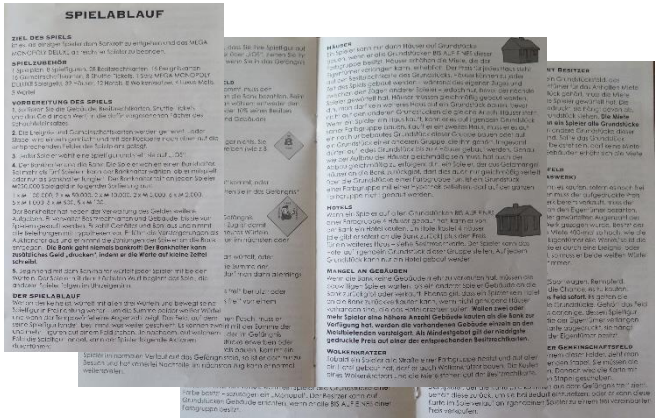
Applications of Monte Carlo Simulations

- Problem that cannot be solved analytically
- Problems that are theoretically solvable, but are very complex
- Illustrate and understand complex processes
- Analyse Game and Investment Strategies

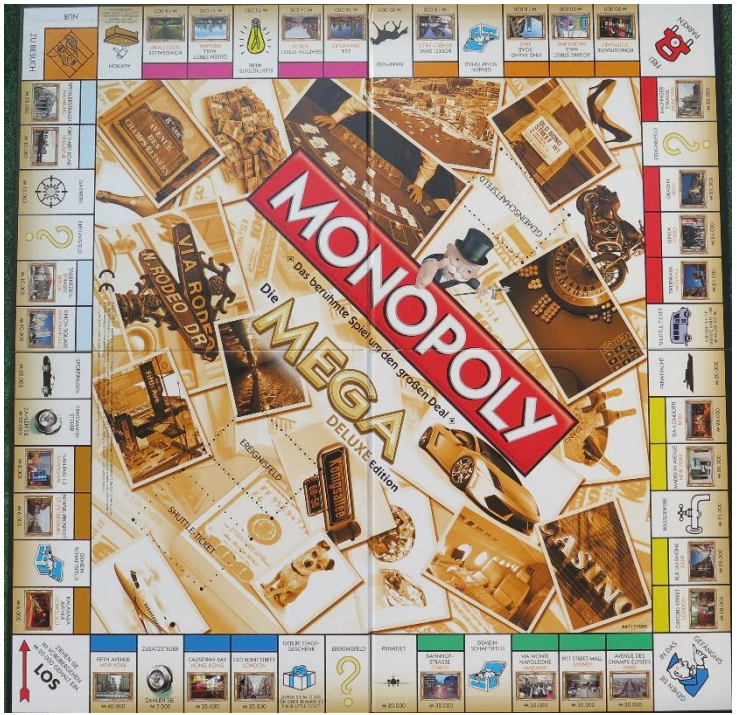
Appliations by Industries

- Simulate Loss Distributions and Claim Events
- Analyse investment strategies
- Simulate production process to detect and understand bottlenecks
- Simulate customer networks in communiation
- Voting pattern
- Weather, climate ,…

The Monopoly® board game is a complex system

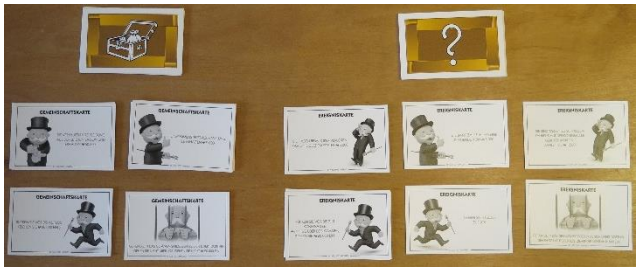


Set of Complex Rules



Framework of Opportunities and Events

Monetary Dimension



Additional Instructions

Random Components

Dynamic Component

Questions of Interest

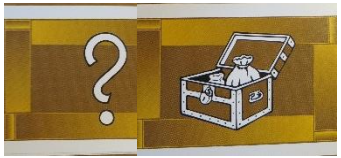
- What is the distribution of visits on the fields of the board game?
- Which fields are most profitable?
- Which fields have a high variability in profitability?

- **These questions can be transferred to many other simulations studies of complex systems.**

Locating the Token – Influential Factors

Sum of
2 Dice

Go to Jail!



Event Fields

Accelerator
Dice

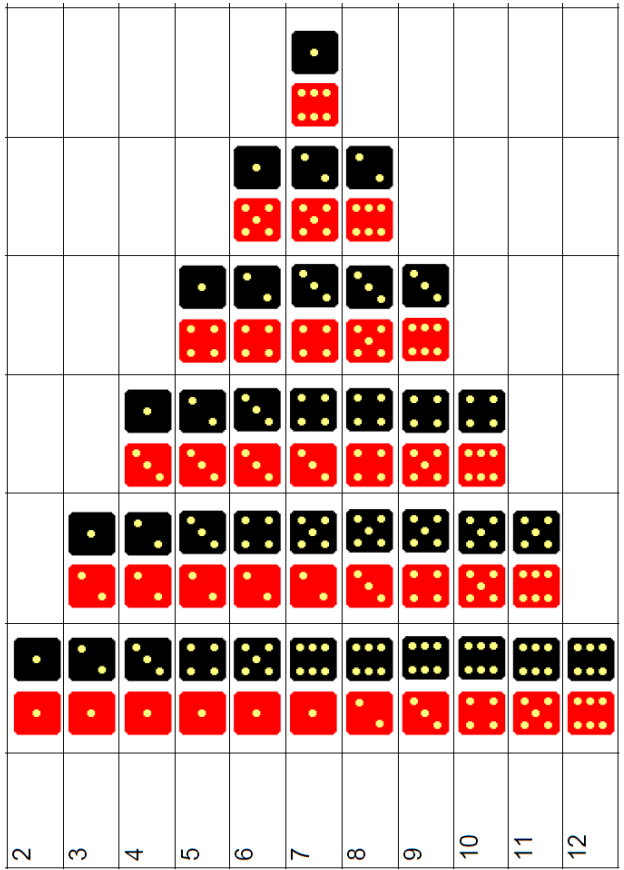
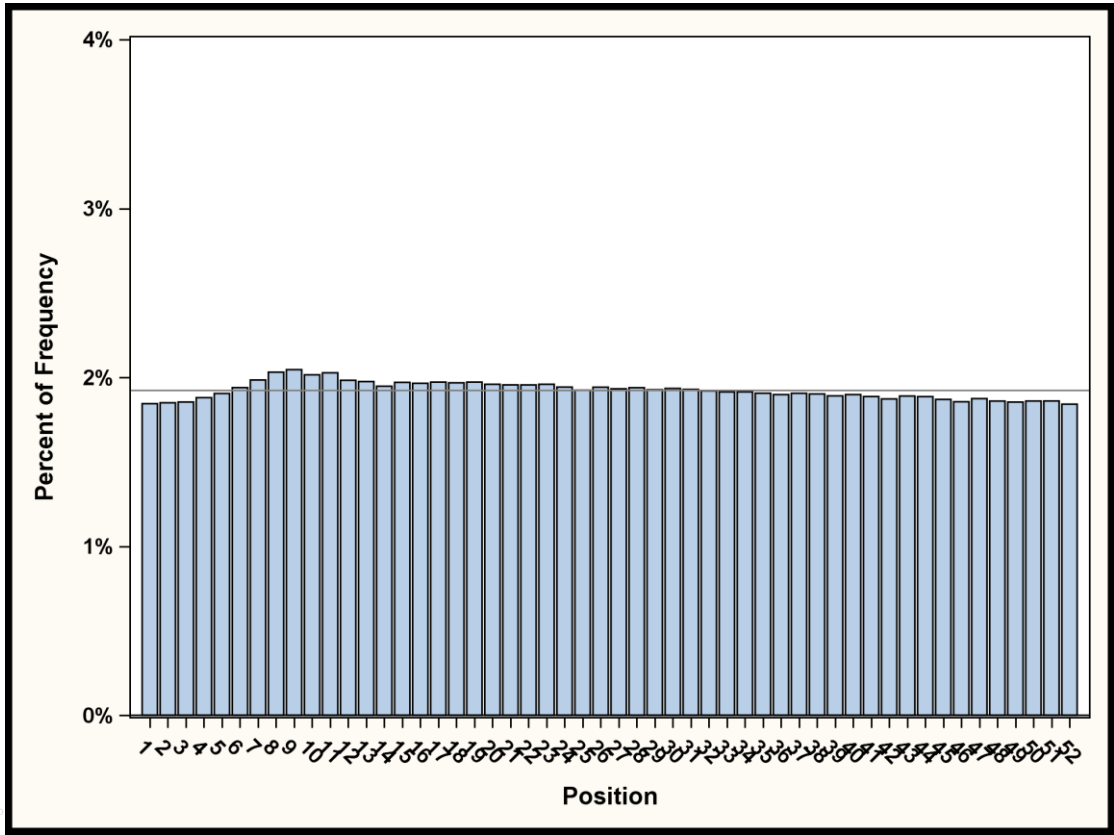


Chart copied from http://www.stat4u.at/

Dice only: Almost Even Distribution

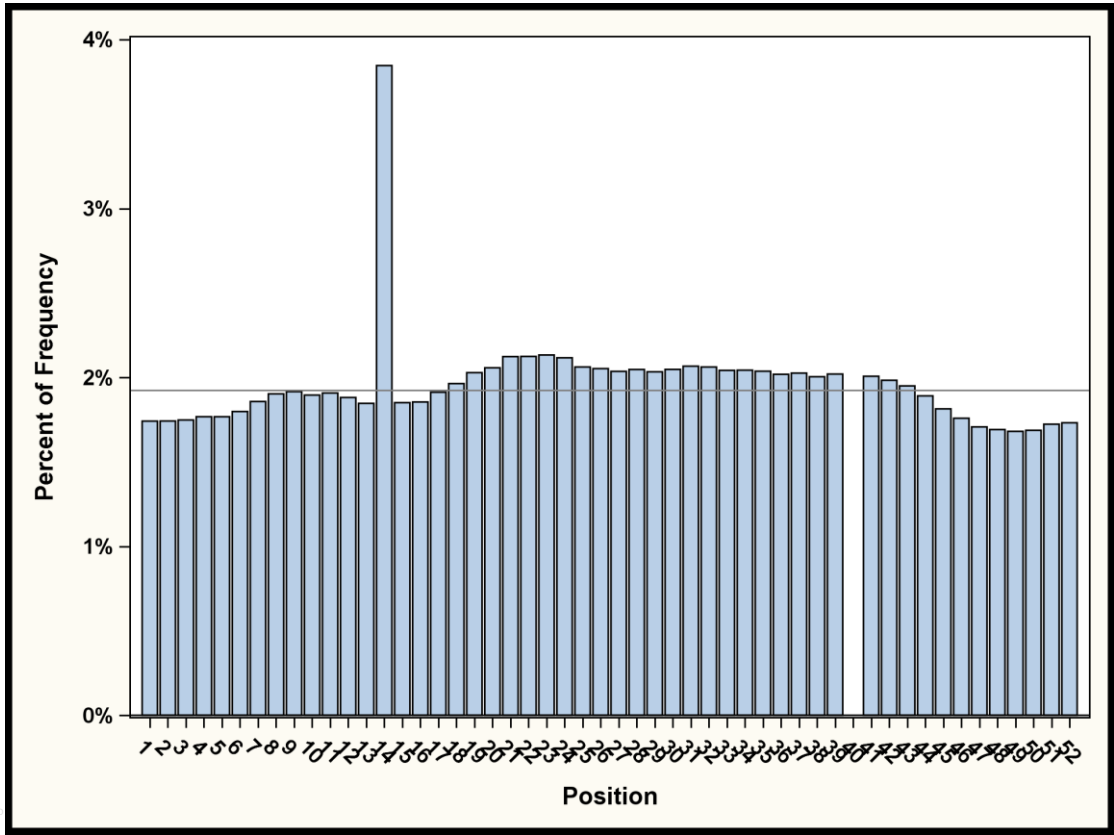
Sum of
2 Dice



All Field-40 visits are relocated to 14

Sum of
2 Dice

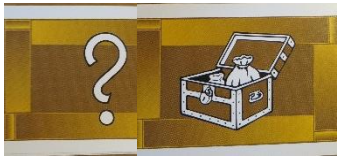
Go to Jail!



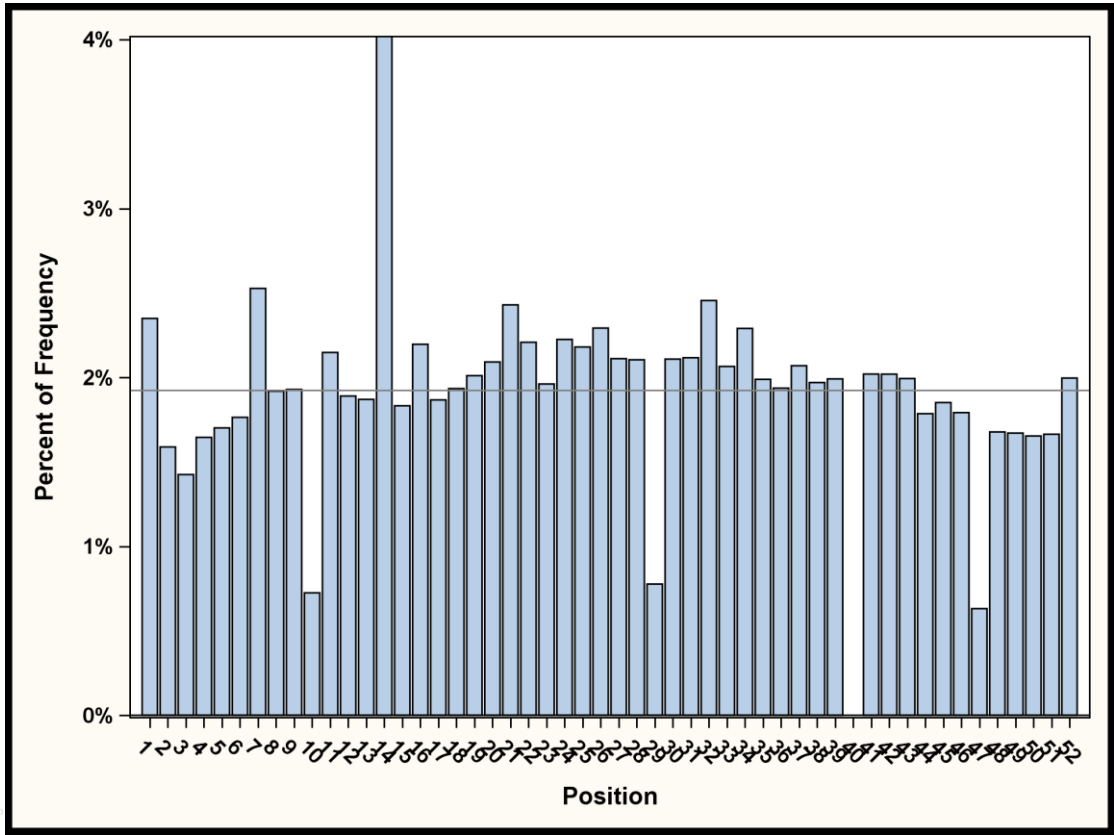
Event Fields relocate to other fields

Sum of
2 Dice

Go to Jail!



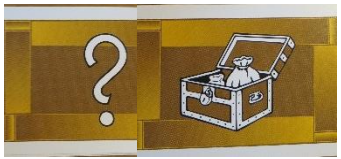
Event Fields



Red Dice introduces high variability

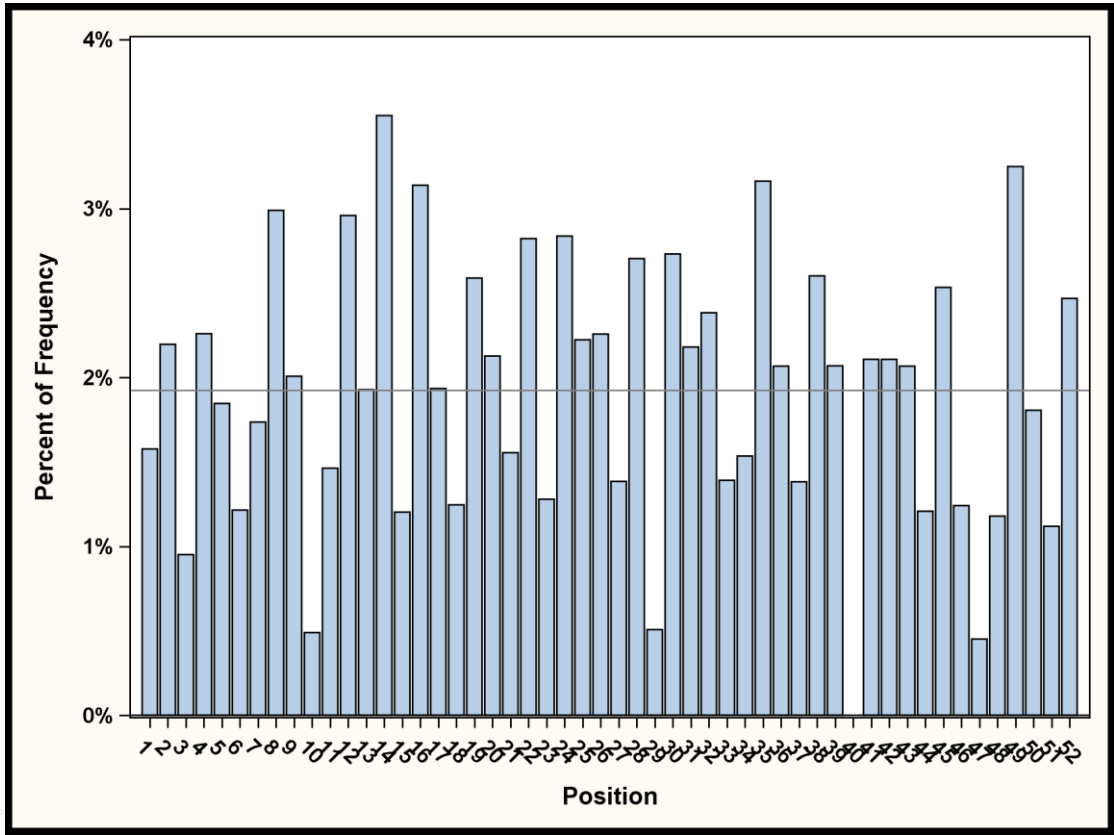
Sum of
2 Dice

Go to Jail!



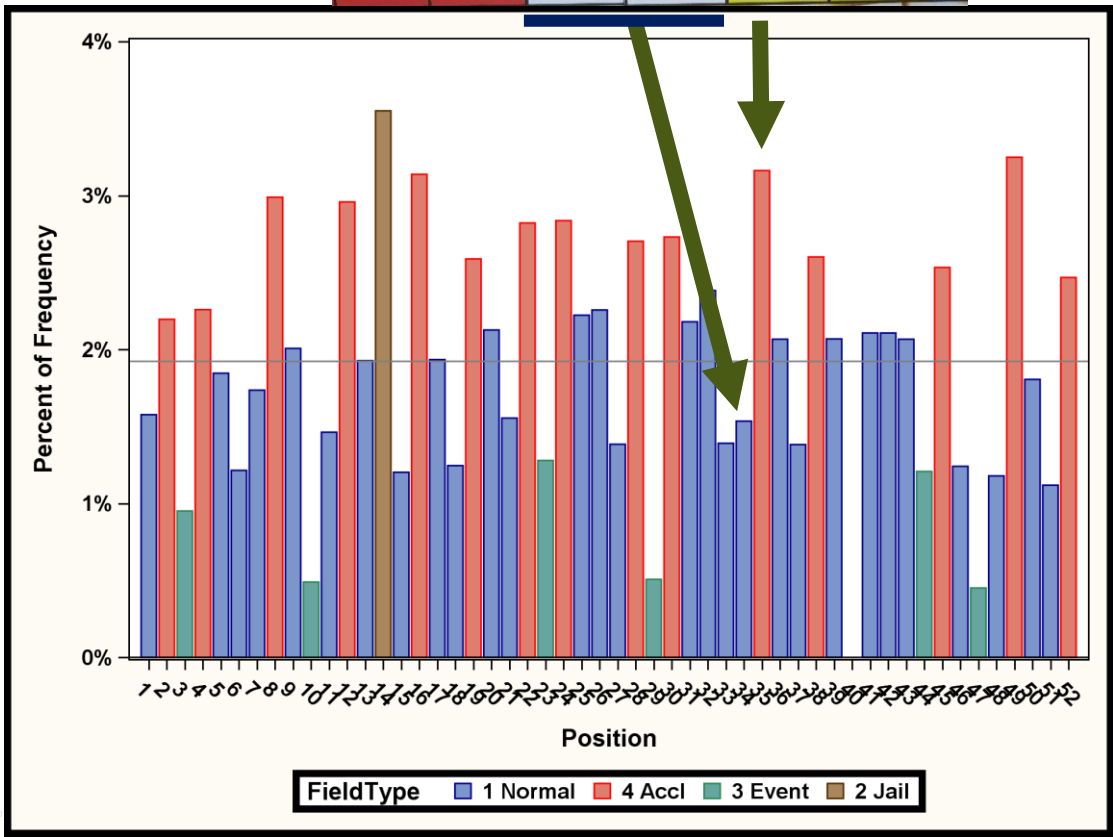
Event Fields

Accelerator
Dice

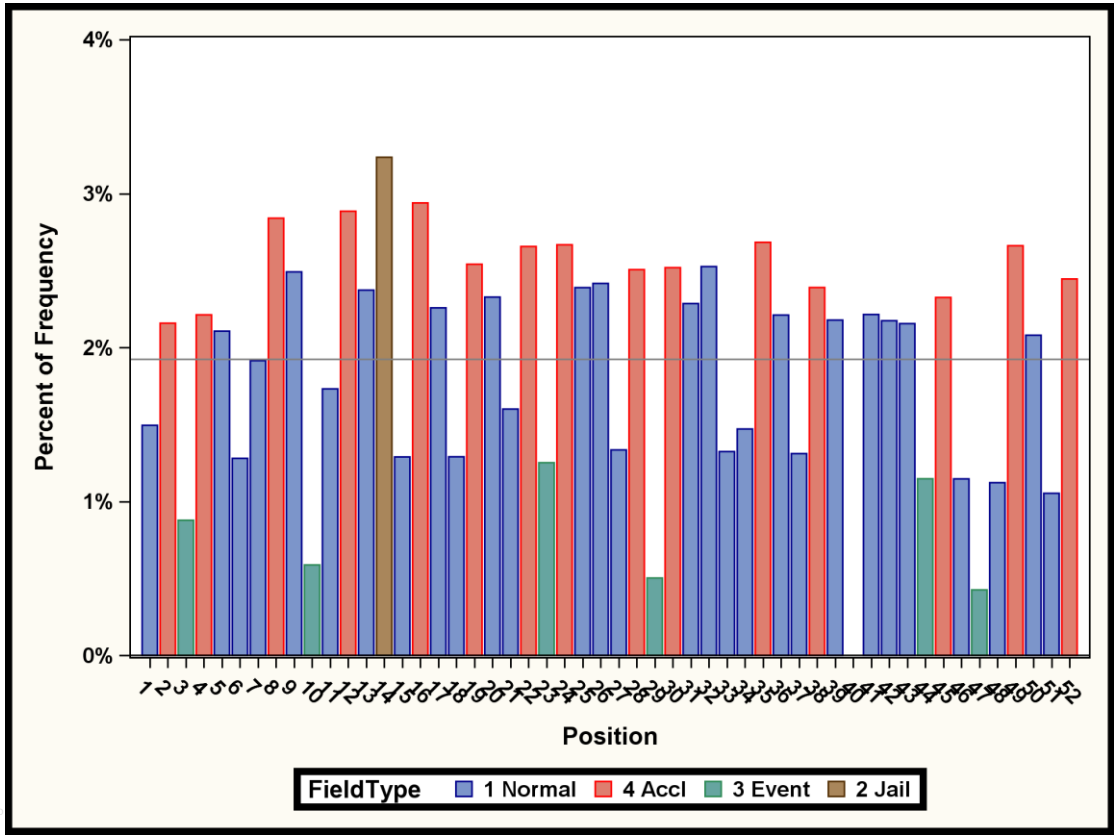


Example for a Relocation

- If the 3rd dice shows the Monopoly® man:
  - Move forward to the next free property-field
  - To the next property field, if all are sold



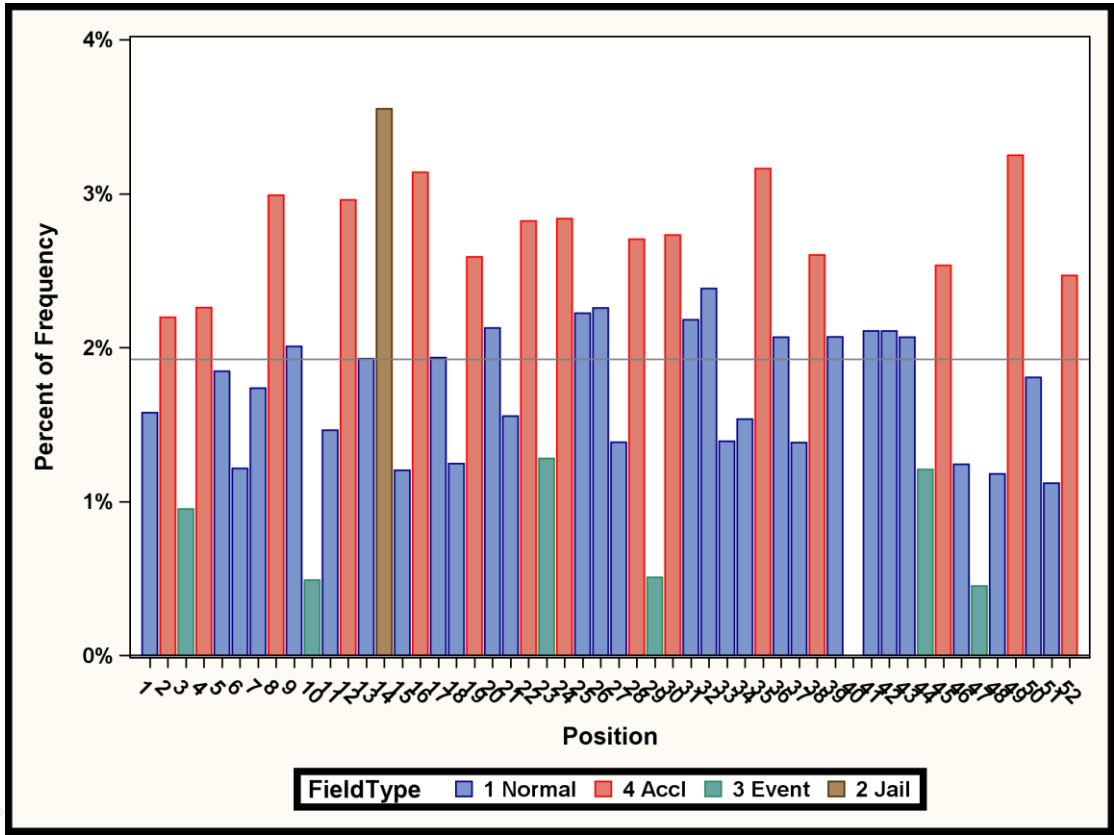
Effect of the accelerator dice after 20 rounds



Effect of the accelerator dice after 70 rounds

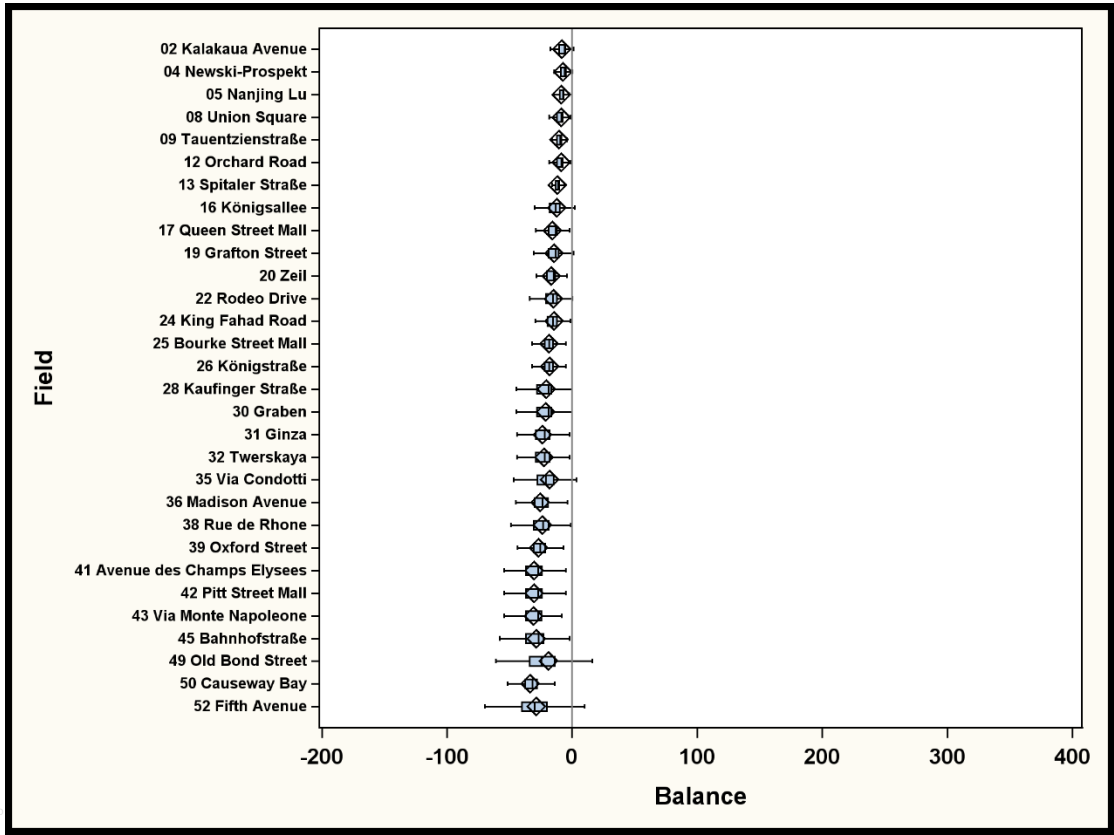
Dynamic Component

- Effect of the rule changes during the course of the game



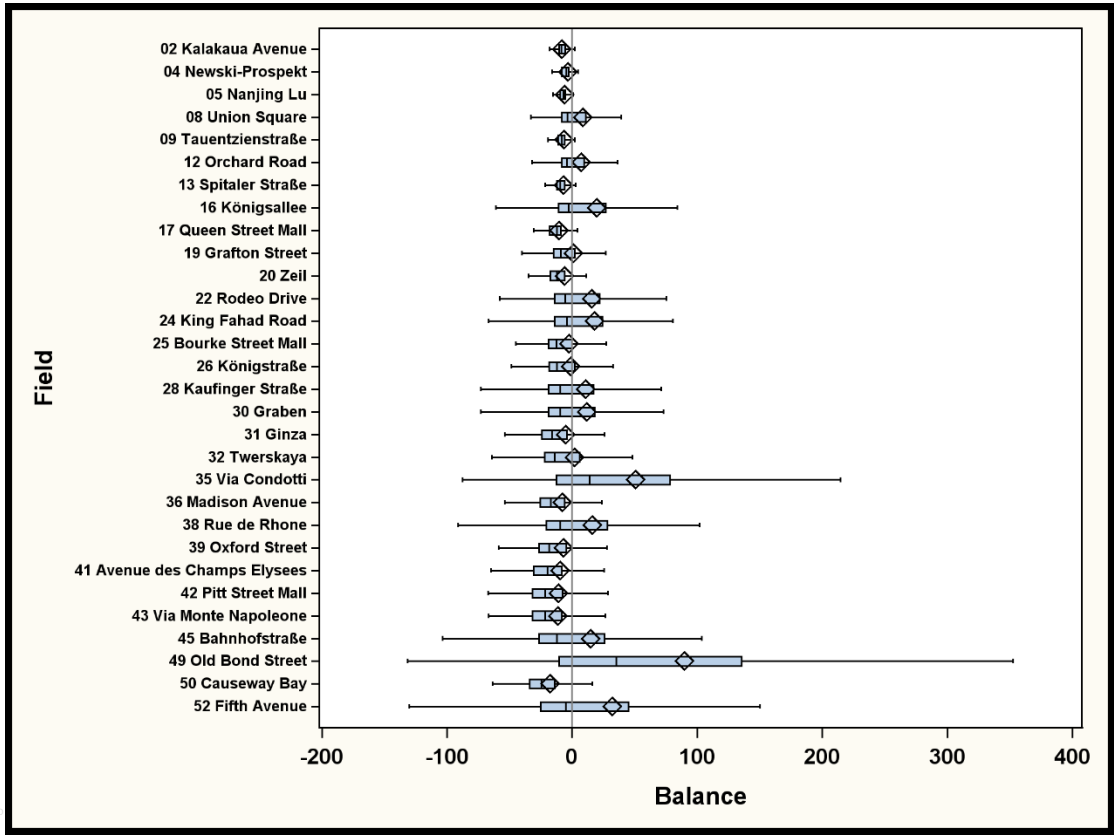
Profitability Distribution after 40 rounds

- Profitability simulation allows you to understand the distribution of the simulation

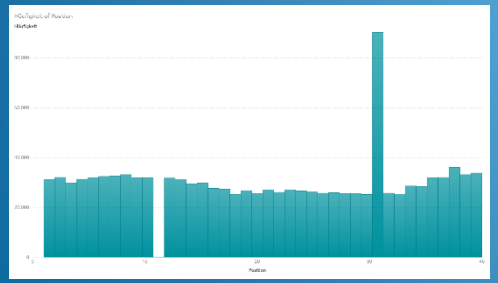


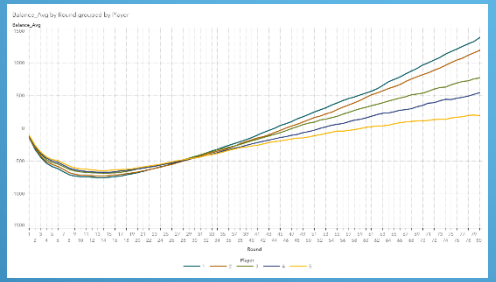
Profitability Distribution after 70 rounds

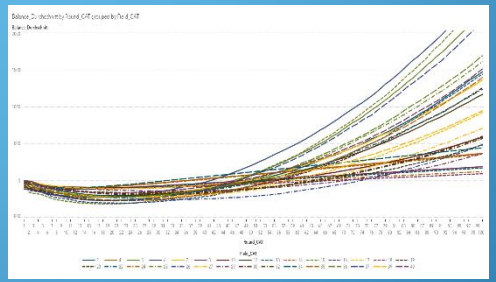
- The expected duration of the game impacts the profitability of different fields



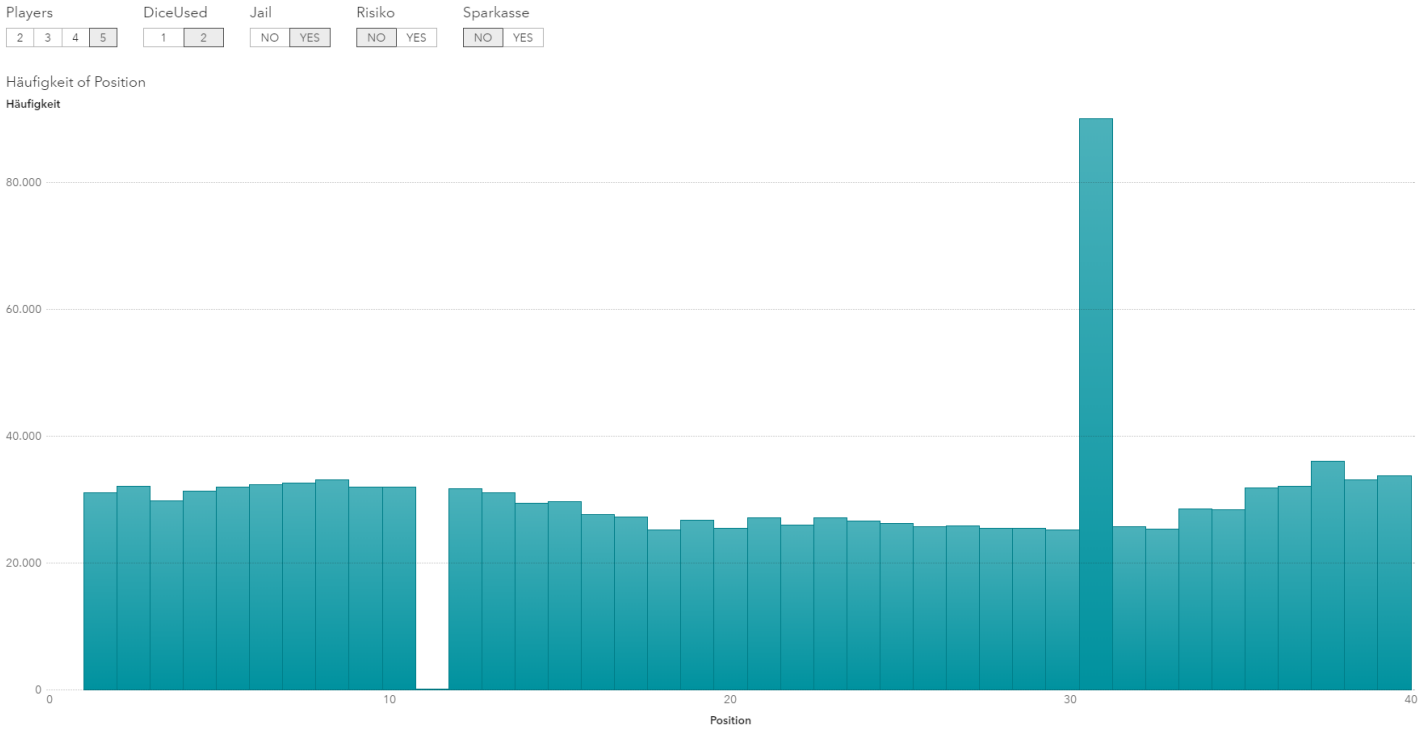
Visualization Examples in SAS Visual Analytics created by my students at the Business School of Burgenland



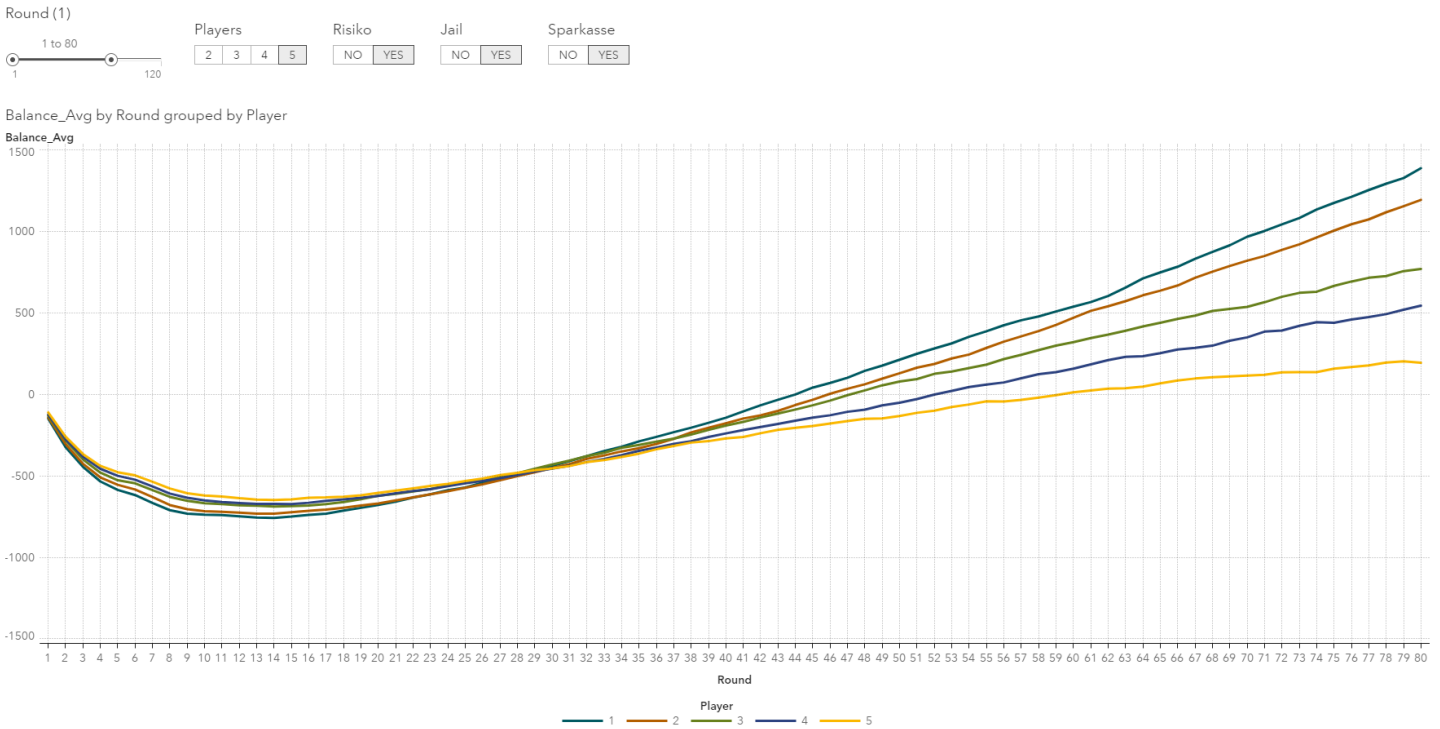




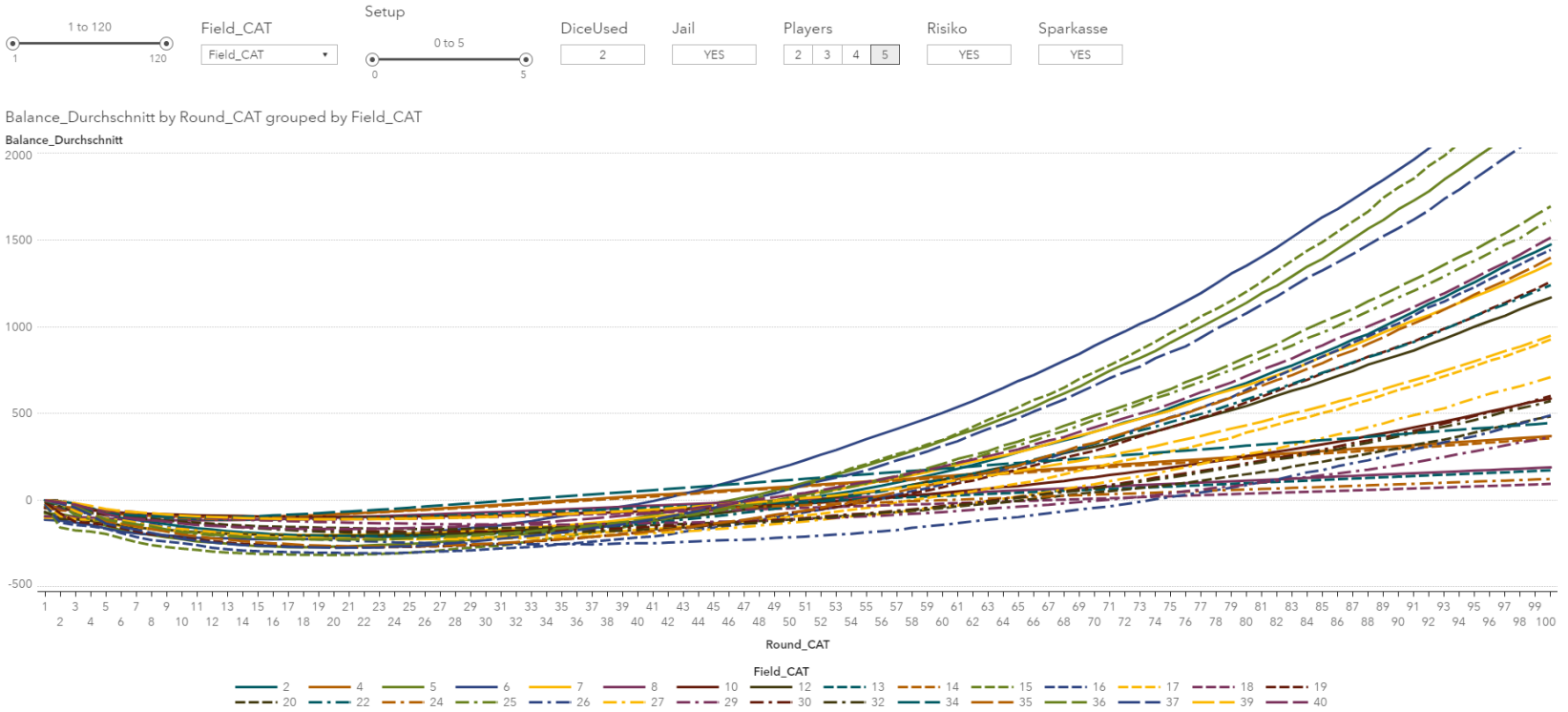
Visualizing different visit frequency scenarios with a barchart



Visualizing the balance per field over the course of the game



Visualizing the balance per player for different numbers of players



Tipps/Tricks when implementing this simulation in SAS

Implementation in SAS

- Declare and Initialize
- Loop over Scenarios (Games)
  - Initialize Scenario
  - Loop over Rounds and Players
    - Generate Random Numbers
    - Follow Instructions
    - Generate Deterministic/Random Behaviour
    - Update Counts, Values, States
    - Output the Record
  - End Loop
- End Loop
- Prepare Analysis Data: Aggreg., Transpose, Enrich
- Calculate Output Statistics, Display Output

```
data Monopoly;
 array PlayerPos {4} PlayerPos1 - PlayerPos4;
   do Game = 1 to 10000;
     do Round = 1 to 70;
       do Player = 1 to 4;
          Dice1 = ceil(rand('Uniform')*6);
          if PlayerPos[Player]=40 then
                        PlayerPos[Player]=14;
          output;
       end;
     end;
   end;
run;
proc transpose data=Monopoly ...;run;
proc sgplot data=Monopoly_TP;
```

Using an ARRAY in a SAS Datastep

```
Array PlayerPos     {&players} PlayerPos1     - PlayerPos&players.      ;
Array PlayerBalance {&players} PlayerBalance1 - PlayerBalance&players.  ;
Array PlayerIncome  {&players} PlayerIncome1  - PlayerIncome&players.   ;
Array PlayerExpense {&players} PlayerExpense1 - PlayerExpense&players.  ;
Array Field         {52}       Field1   - Field52       ;
Array FieldSetup    {52} FieldSetup1    - FieldSetup52  ;
Array FieldRevenue  {52} FieldRevenue1  - FieldRevenue52;
Array FieldCost     {52} FieldCost1     - FieldCost52   ;
Array FieldBalance  {52} FieldBalance1  - FieldBalance52;
```

- **PLAYERPOS[2]** denotes the position of player 2 and refers to variable PLAYERPOS2
- **PLAYEREXPENSE[Player]** refers to the player expense variable for the respective player.
- **FIELDREVENUE[PLAYERPOS[PLAYER]]** refers to the revenue of that field, where the actual PLAYER is currently positioned.

Using a SAS Format as Lookup Table

	Field	M0	M1	M2	M3	M4
1	2	0.2	1	3	9	16
2	4	0.4	2	6	18	32
3	5	0.5	3	8	24	36
4	8	0.6	3	9	27	40
5	9	0.6	3	9	27	40
6	12	0.6	3	9	27	40
7	13	0.8	4	10	30	45
8	16	1	5	15	45	62
9	17	1	5	15	45	62
10	19	1	5	15	45	62
11	20	1.2	6	18	50	70

```
data k0;
 set Property_CostRevenue;
 fmtname = 'k0_';
 type = 'i';
 rename field=start k0=label;
run;
```

```
proc format cntlin=k0 library=work;
run;
```

Verwenden der Formate und Arrays

```
if Field[PlayerPos[Player]] = 0 then do;
      Field[PlayerPos[Player]]= Player;
      FieldCost[PlayerPos[Player]]= input(PlayerPos[Player],K0_.);
      FieldSetup[PlayerPos[Player]]= 0;
      PlayerExpense[Player]=
            PlayerExpense[Player] + input(PlayerPos[Player],K0_.);
end;
```

Moving the Token

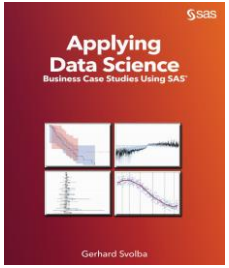
```
do Round = 1 to &Rounds;
    do Player = 1 to &players;
          Dice1 = ceil(rand('Uniform')*6);
          Dice2 = ceil(rand('Uniform')*6);
          Dice3 = ceil(rand('Uniform')*6);
          *** Dice3 shows a number Number
              that shall be added to the sum;
          if      Dice3 <= 3 then DiceSum =
                                  sum(Dice1,Dice2,Dice3);
          else                    DiceSum = sum(Dice1,Dice2);
       PlayerPos[Player] + DiceSum;
       PlayerPos[Player] = mod(PlayerPos[Player]-1,52)+1;
```

Summary

- Monopoly Game as “Illustration”
- Analogies with real business life
  - Decisions about investments need to be made.
  - Information not only about the expected value, but also about the variability is needed.
  - Strategies and decisions can change in the course of a game
- SAS is a powerful tool to perform and study simulation case studies (Datastep, DS2, CAS, IML, Analytic Procedures, Visualisation)

Analytics and Data Science is there to help you!

- Get a clearer, more objective picture of your data and your analysis subjects
- Get explicit results instead of searching the needle in the haystack
- Make your data talk to you!
- Receive findings automatically instead of manually
- Do it again! – treat models as an asset and repeat your analysis



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Für meine Eltern und meine Großeltern.
(To my parents and my grandparents)

In the late 1970s my grandmother from Burgenland came to visit us in Vienna for two weeks. I still remember that time. Every morning before I went to school, I prepared the DKT board game (which is a very popular equivalent to the Monopoly board game in Austria) to be able to start playing with her immediately when I came home from school. And she played with me the whole afternoon, every day. She lost every game, and it always ended with a huge debt amount for her. But she never complained or wanted to do anything else. Spending time with us, the children, was a priority for her. And that was always true for my parents and all my grandparents: We, the children, were always important to them.
I enjoyed having fun, listening to self-invented stories, being at the lake, inviting friends, constructing boats, and other stuff, but I also appreciated knowing that you have to work hard and be patient, modest, and persistent to achieve your goals. I learned very early that a happy life has many dimensions. Today I am aware that there are so many things from that time that I could take with me into my professional life and that made me successful.
Finishing this book beside a highly intensive full-time job as a SAS consultant and part-time lecturer at universities was a very hard trial for me. And I finally succeeded. The fact that this book ends with the simulation case study of the Monopoly board game is an essential piece that completes a comprehensive picture.
It is my way of saying “Thank You” to my parents and my grandparents for so many things.